

BACKGROUND ION EMISSION FROM TUNGSTEN FILAMENTS

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There is considerable interest in producing tungsten filaments with very low background ion emission for surface ionization detectors and mass spectrometers.^{1,2,3,4,5} This background ion emission is suggested herein to be the result of two processes: (1) volume diffusion and (2) surface diffusion. The purpose of this article is to document the volume diffusion process and discuss, admittedly on the basis of a meager amount of data, the two possibilities mentioned above.

Many workers^{1,2,4,5} have reported a background ion emission from "pure" tungsten filaments, which is not substantially reduced by baking. It has been found that the majority of these ions are potassium.^{1,6}

¹R. E. Minturn, S. Datz, and E. H. Taylor, Jour. Appl. Phys. 31, 876 (1960).

²E. F. Greene, Rev. Sci. Instr. 32, 860 (1961).

³J. W. Frazer, and G. W. Barton, Rev. Sci. Instr. 30, 370 (1959).

⁴P. J. Groblicki, "The Production of Pure Tungsten", Senior Thesis, Brown Univ. (1959).

⁵R. W. Roberts, "The Scattering of a Potassium Atomic Beam by a Crossed Beam of Bromine Molecules", Ph. D. Thesis, Brown Univ. (July 1959).

⁶A. Riddoch, Proc. Phys. Soc. 72, 467 (1958).

The filament reported herein is 0.0024- by 1.0-inch "ultrapure" undoped tungsten wire obtained from Westinghouse and is identical to the wire used by Roberts.⁵ The filament is biased approximately +90 v above the collector as shown in fig. 1. The ion current was measured by a Cary Instruments Model 31 Electrometer driving a strip chart recorder.

The filament was brought rapidly up to 1350° C at $t = 0$ (fig. 2) and the collector current recorded. An initial transient of about 3 min duration was observed before the constant background emission was reached.

Solution to the diffusion equation for an infinite cylinder with constant diffusion coefficient, D , and diameter, d , yields the following expression for ion current emitted from a length, L , (by using 100-percent surface ionization efficiency for the potassium)⁷:

$$I(t) = 4\pi LeND \sum_{n=0}^{\infty} \exp\left[-\left(\frac{2\alpha_n}{d}\right)^2 Dt\right] \approx 4\pi LeND \exp\left[-\left(\frac{2\alpha_0}{d}\right)^2 Dt\right] \quad (1)$$

where e is the electron charge, N is the initial concentration of impurity in the wire, and α_n is the n^{th} zero of the zero order Bessel function of the first kind. When the approximate form of equation (1) is used, the slope of the straight-line portion of the data curve on the semi-log plot in fig. 2 gives $D = 2.68 \times 10^{-8}$ cm²/sec, and the intercept of this straight line with the ordinate gives $N = 4.98 \times 10^{13}$ impurity atoms/cc. This corresponds to an impurity concentration of 7.9×10^{-8} percent. The

⁷E. Ya. Zandberg, Soviet Phys.-Tech. Phys. 2, 2399 (1959).

data above the straight line at times less than 40 sec cannot be fully accounted for by the higher order terms in equation (1); they may be due to thermally induced mechanical strains, which are known to affect emission.

The total number of impurity atoms emitted as ions during the $17\frac{1}{2}$ -hr bakeout period was 4×10^{10} . The volume diffusion analysis gave only 4×10^9 as the total number of impurity atoms initially in the filament.

One may have reasonable doubts about the reliability of such a simple diffusion model and its ability to produce the true magnitude of the initial impurity concentration. To strengthen the credibility of the model, equation (1) was applied to the data of Riddoch and Leck.⁶ They report an initial transient ion current when they bring a tungsten filament up to 500°C . Their filament was fabricated from 0.001 in.-diam. commercial grade tungsten, which was said to contain about 0.01 percent impurities. They found the majority of this impurity to be potassium. A semi-log plot of their data is presented in fig. 3. Fitting this data to equation (1) yields $D = 4.0 \times 10^{-8} \text{ cm}^2/\text{sec}$ and $N = 5.0 \times 10^{19}$ impurity atoms/cc, which corresponds to 0.08 percent impurity.

Volume diffusion appears to be inadequate to explain the persistent background ion emission of a high-purity filament. Surface diffusion from the filament supports is a possibility. Minturn, Datz, and Taylor¹ have pointed out the sensitivity of this impurity emission to surface

conditions, specifically, oxygen coverage. They further point out that potassium ionization efficiency is not sufficiently affected by the oxygen film to explain the observed increase in ion emission. The film could, however, affect the surface diffusion rate.

The ion current resulting from surface diffusion may be estimated by using the surface diffusion coefficient; Bosworth⁸ reported a value of 2.8×10^{-3} cm²/sec for potassium on tungsten at 500° C. If the surface of the filament at the support had a coverage of 10^{12} atoms/cm² maintained by the support impurity and the filament within the collector had no coverage, the ion current would be of the order of 10^{-12} amp.

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⁸R. C. L. Bosworth, Proc. Roy. Soc. A 154, 112 (1936).

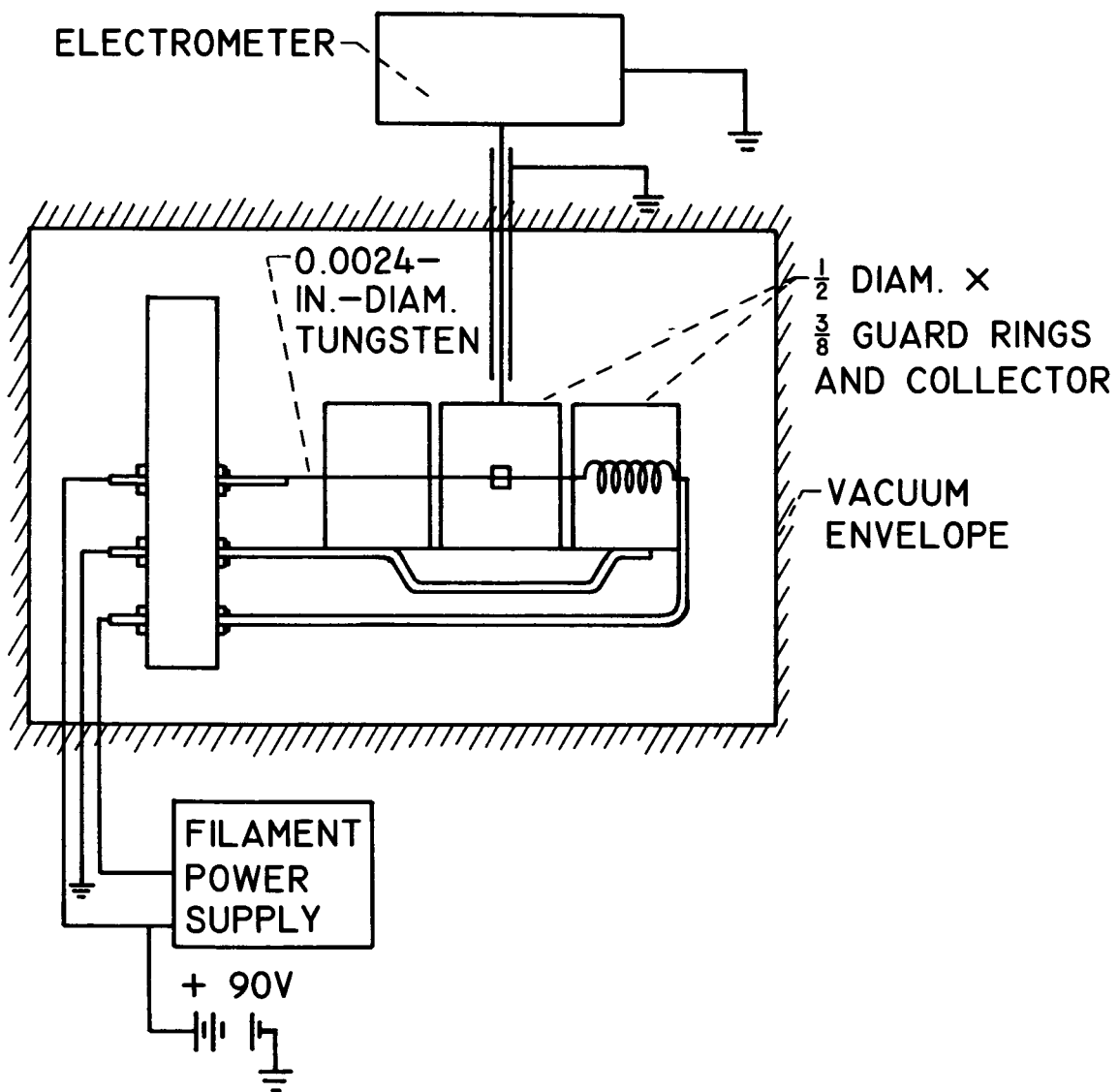


Fig. 1. - Filament assembly: surface ionization detector.

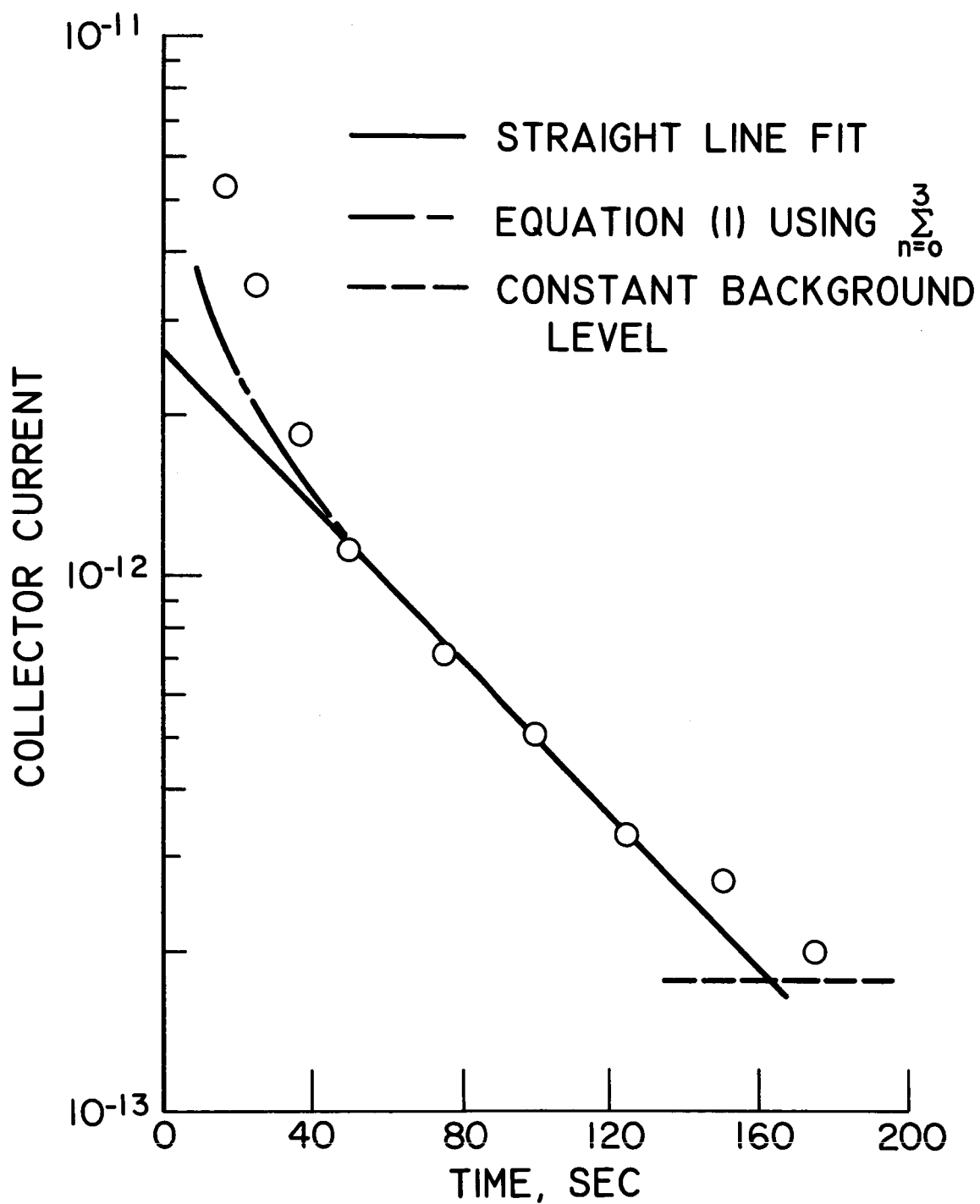


Fig. 2. - Background ion current transient from 0.0024-in.-diam. tungsten filament at 1350° C.

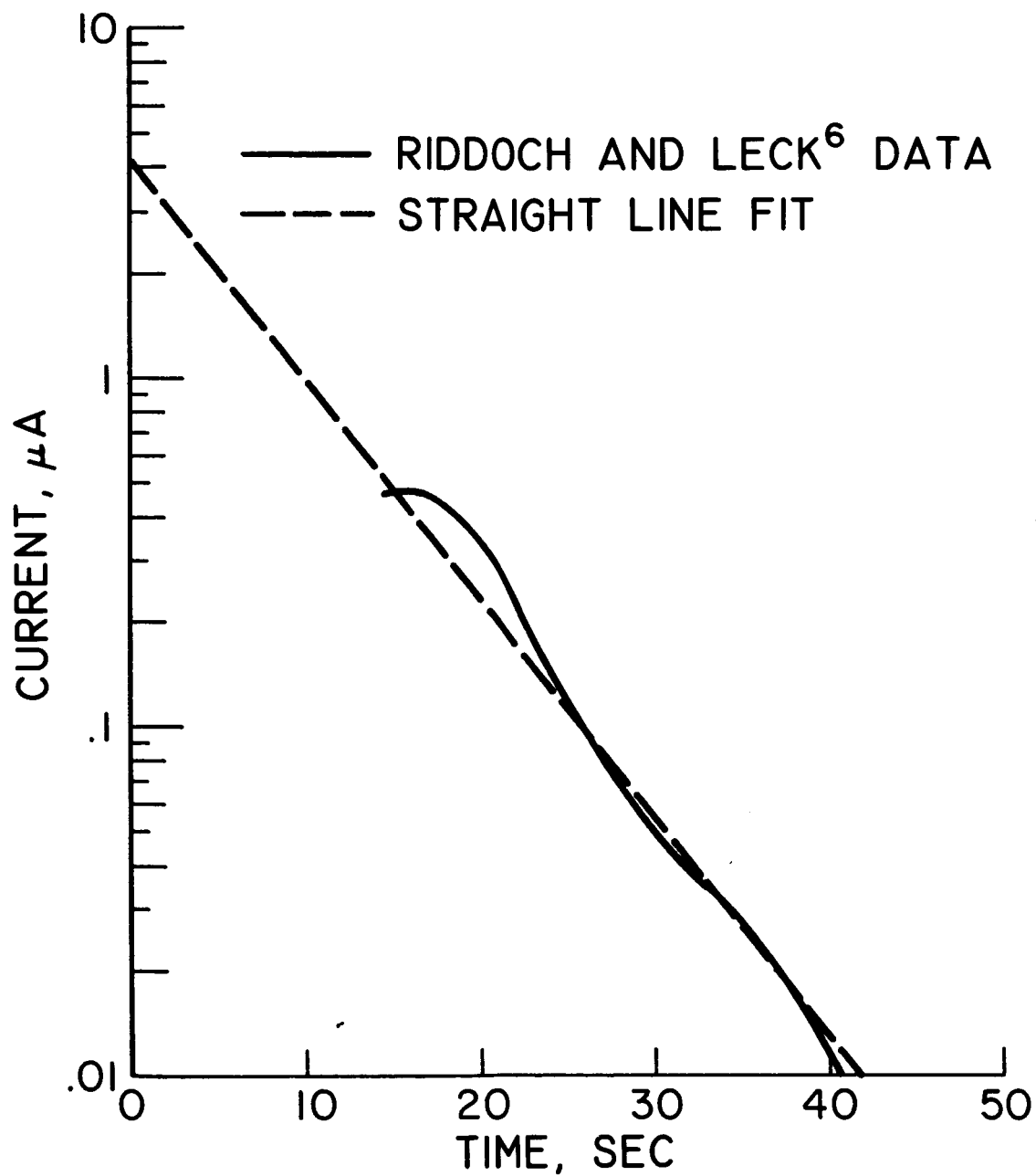


Fig. 3. - Transient ion current observed by Riddoch et. al.⁶ when a tungsten filament (0.001 in. diam. was heated to 500° C.